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MELBOURNE, VICTORIA

Propulsion Technical Memorandum 449

FLIGHT TESTING OF TWO ALLISON T56 ENGINES MODIFIED TO THE ARL DEVELOPED LOW SMOKE CONFIGURATION

by

P.N. Doogood

Approved for public release.

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SUMMARY

Two further Allison T56 engines have been modified to the ARL developed low smoke configuration and placed "on wing" of separate RAAF P-3C Orion aircraft for extensive flight testing. The initial tests are reported in this document and it is concluded from these that the modification has had no adverse effect on the performance of the engine.

POSTAL ADDRESS: **Director, Aeronautical Research Laboratory,**
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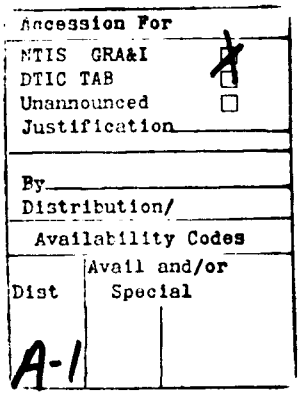

1. INTRODUCTION

Nine months after the first Allison T56 Engine modified to the ARL Low Smoke configuration went on to the wing of P-3C Orion A9-661 (Reference 1), the engine had logged over 550 hours in normal squadron operations without incident (Figure 1).

Two further engines were subsequently modified and placed on P-3C aircraft A9-756 and A9-751 in numbers 3 and 4 positions respectively. This document describes the successful flight testing, and qualification for normal operations, of both these engines.

2. THE ENGINES

The T56 engine has been described in detail in previous ARL publications (References 2 and 3) on smoke reduction. The engines referred to here, Serial No AE112245 and AE110351, are both T56-A-14 Series III types. They were taken from the hot end overhaul line at Qantas Maintenance Base in Sydney and in standard form were calibrated for smoke emission in that Company's Prop-Jet Test Cell (Figure 2).

The combustion chambers were removed and modified, and the engines reassembled. The smoke emission tests were then repeated in the Qantas Test Cell (Reference 4).

3. FLIGHT TESTING PLAN

The original plan for flight testing of these two engines, as proposed by the Royal Australian Air Force (RAAF) Aircraft Research and Development Unit (ARDU), had called for testing of both engines, before and after modification, on the one aircraft in numbers 2 and 3 position to measure engine performance. For a number of reasons these ARDU test flights were rescheduled for the middle of 1990.

In the interim, the two engines were released to 492 Squadron at the RAAF Base Edinburgh, South Australia to be installed in modified form in aircraft during normal engine changes. This was to be done at the RAAF unit's convenience in any of numbers 2, 3 or 4 positions. Subject to successful completion of a test flight schedule, which was based on the standard post installation test flight plan designed to test the operability and behaviour of the modified engines over the entire flight envelope, the engines would be released for normal squadron operations to provide increased confidence of flight crews in the reliability of the modification.

The test flight schedule was to prove operational integrity of the modified engines once fitted to aircraft; Air Eng 2B Office of RAAF Headquarters Logistic Command and Aeronautical Research Laboratory (ARL) formulated the additional maintenance test flight requirements with assistance from various RAAF personnel. These requirements were based on the safety of flight checks carried out by RAAF 92 Wing on the first modified engine on A9-661 as reported in Reference 1.

The additional tests incorporated in the maintenance test flights for modified engines were:

a. Relight checks at 1,000, 15,000 and 25.000 feet. The modified engine is to be shut down and cold soaked for 30 minutes before restarting. Restarts should be at the maximum allowable restart airspeed (minus 15 kts at 1,000 feet to minimise the chance of propeller decoupling occurring).

b. The aircraft is to be subjected to flight manoeuvres at selected points in the aircraft flight envelope.

c. Maximum reverse thrust power is to be used on the modified engine on landing.

d. The aircraft is to be taxied through the aircraft washing facility (birdbath) with the modified engine operating.
Throughout the tests, engine behaviour was monitored by visual observation and by video recording of the cockpit engine instruments.

4. FIRST FLIGHT TEST

The first engine in the current tests to go "on wing" was No AE112245 and it was installed into number 3 position on P-3C A9-756. The flight was scheduled for 1000 hours on 9 March 1990 but it was delayed until 1145 hours on the 10th.

The crew for the flight was:

CAPTAIN - Flight Lieutenant Kris Krawinkel,

CO PILOT - Flight Lieutenant Ross Langley,

FLIGHT ENGINEERS - Warrant Officer Dave Jones and Sergeant Lex Glasby,

ARL FLIGHT TEST OBSERVER - Mr Peter Doogood.

Take off was normal as was the climb to 10,000 ft where the standard post installation engine shut down tests were carried out. These tests were incident free but shortly after the engine was restarted for the second time, W/O Jones noticed oil leaking from the labyrinth seal bleed and running over the top of the wing. After a brief discussion with the Captain, the engine was shut down again and the aircraft returned to Edinburgh where it landed on three engines at 1330 hours.

The engine fault was found to be minor and was quickly corrected; the test flight resumed at 1500 hours with a climb to 25000 ft. at which the modified engine was again shut down. The aircraft circled until the turbine inlet temperature (TIT) on the test engine was reduced to 28°C. Figure 3 is reproduced from the video record of cockpit instruments at this condition. With the aircraft flying at 170 knots the propeller was un-feathered and allowed to windmill up to a stable r.p.m. when the fuel and ignition were switched on. The engine fired up with TIT rising quickly to 700°C and then settling back to 535°C. Table 1 contains a collation of relevant engine data recorded during these tests.

The above test was successfully repeated at 15000 ft and 1000 ft; between these levels (8000 ft) the aircraft was stalled and recovered and the modified engine behaved exactly as the others, showing no tendency to flame out or lose power.

The aircraft returned to Edinburgh at 1730 hours, where the test engine successfully underwent the reverse thrust and water ingestion tests.

5. SECOND FLIGHT TEST

The second engine, No. A110351, was installed in the number 4 position on aircraft No. A9-751 and was to fly at 1000 hours on 16 March but the flight was delayed due to failure of the emergency shut-down cable.

The aircraft was declared serviceable on 21 March and the flight commenced at 1500 hours on that day.

The crew for the flight was:

CAPTAIN - Wing Commander Jim Brown,

CO-PILOT - Flight Lieutenant Norm Gallagher,

FLIGHT ENGINEERS - Sergeant Peter Robjent and Sergeant Andy Ortlepp,

ARL FLIGHT TEST OBSERVER - Mr Peter Doogood.

Prior to take-off an additional test which had not been carried out in previous trials, the "taxi start", was undertaken. This requires the aircraft to taxi down the runway at high speed, initially with the test engine shut down. The propeller is un-feathered and the engine windmills up to starting r.p.m. when fuel and ignition systems are activated to start the engine. This test was successfully carried out. Take-off was normal and at an altitude of 8000 ft the standard engine change tests were performed successfully.

The aircraft was then taken to 25000 ft, the test engine shut down and cold soaked (Figure 4). After half an hour the TIT was down to 26°C; the Co-Pilot and Flight Engineer then began the checks for a restart. The restarts were carried out without incident at 180 knots although the Captain did comment on a slight lag in the time taken for the TIT to stabilise at 480°C. The test was repeated with a TIT of 70°C and on this occasion the apparent lag did not reoccur.

The aircraft then entered a high speed descent at 300 knots to 15000 ft with the TIT on the test engine rising to 1084°C and the indicated horse power to 3800.

Again at 15000 ft the engine was cold soaked down to a TIT of 22°C. The times after relight to 760° peak and 500° stable temperatures (Table 2) were again well within limits according to the Captain..

At 12000 ft the Captain reduced the airspeed of the aircraft to 120 knots where the aircraft was stalled, resulting in some shaking from turbulence. This manoeuvre had no effect on number 4 engine which was pushed to 1020° TIT and 3500 HP during the recovery. Once again the aircraft was put into a high speed descent at 300 knots and during this manoeuvre the number four engine was throttled back to flight idle power with a TIT of 550° indicated. This test was carried out to explore for lean extinction; the engine, however, remained stable throughout the manoeuvre.

The cold soak test at 1000 ft was done at 210 knots and was again quite successful, as was the use of maximum reverse thrust on the test engine when the aircraft landed at 1730 hrs. After landing, the aircraft taxied into the "birdbath" and the test engine was subjected to the full water ingestion test. It ran at ground speed idle (TIT 610^{O}C) and remained stable throughout.

6. CONCLUSIONS

These engine flight tests, together with that previously carried out in in June 1989, have shown that the modifications, made to the combustors to reduce smoke emission from the T56 engine, have no negative effects on the engine operability and behaviour.

The extreme flight manoeuvres carried out in the tests were designed to test the tolerance of the modified engine to inlet flow distortion; in particular to detect any tendency to flame-out. At no stage in the flights did this occur and the Captains of both aircraft expressed their complete confidence in the test engines. Elapsed times between cold soaking and stable TIT's after relight (Tables 1 and 2) were well within tolerance, and windmill starting and full reverse thrust performances were normal.

7. ACKNOWLEDGEMENTS

The author would like to thank the crews of both aircraft (names in text) for their confidence in the modified engines and their enthusiastic co-operation in the planning and conduct of the test flights.

Thanks are also due to FLTSGT Ross Willett of 492 Squadron RAAF Edinburgh and SGT Chris Buley of RAAF Logistic Command for their assistance in the planning of the flights and arrangement of accommodation at Edinburgh for the author.

Finally, the assistance given to the author by David Parslow of ARL, John King, Ron Bennett and the Test House Crew at Qantas, in the conduct of the smoke calibration trials on the test engines is greatly appreciated, as is the direction of Frank Skidmore of ARL, which contributed to the successful culmination of the test flights.

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A/C No. A9-756 ENG No. AE112245 POSITION ON WING 3

		TIT (^{0}C)			TIME FROM IGNITION(SECS)	
ALTITUDE	**AIR SPEED (KNOTS)**	**ENG START**	**PEAK**	**STABLE**	**PEAK TIT**	**STABLE TIT**
25000 FT	180	30	700	535	7.42	8.79
15000 FT	200	26	720	500	7.08	8.54
1000 FT	240	30	700	530	7.20	8.04

TABLE 1 FIRST FLIGHT TEST 10 MARCH 1990

A/C No. A9-751 ENG No. AE110351 POSITION ON WING 4

		TIT (^{0}C)			TIME FROM IGNITION (SECS)	
ALTITUDE	AIR SPEED (KNOTS)	ENG START	PEAK	STABLE	PEAK TIT	STABLE TIT
25000 FT	180	32	700	480	7.27	8.35
25000 FT	180	70	700	540	5.20	6.41
15000 FT	240	22	760	500	5.90	6.80
1000 FT	210	32	700	540	7.77	8.87

TABLE 2 SECOND FLIGHT TEST 21 MARCH 1990

FIGURE 1. P3-C ORION A9-661.

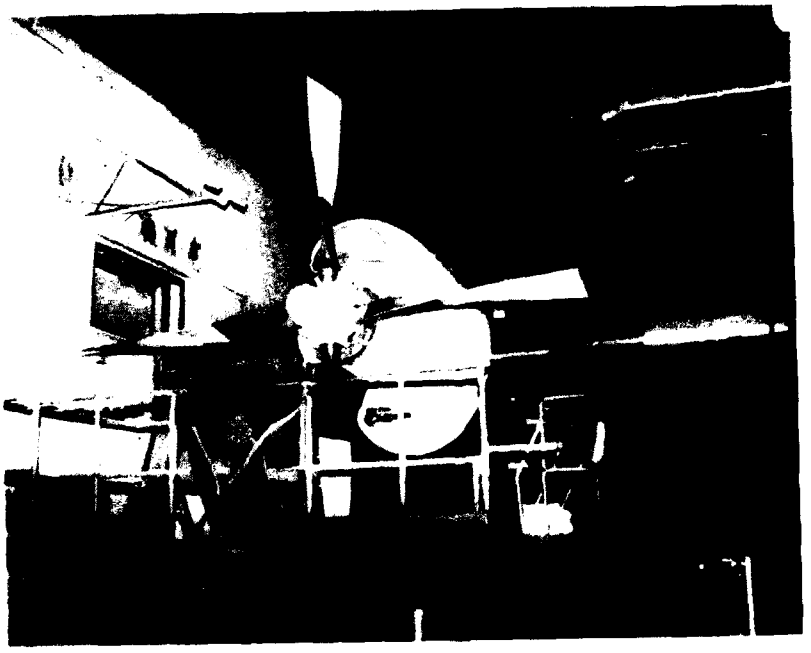

FIGURE 2. T56 ENGINE No AE112245 IN QANTAS PROP-JET TEST CELL.

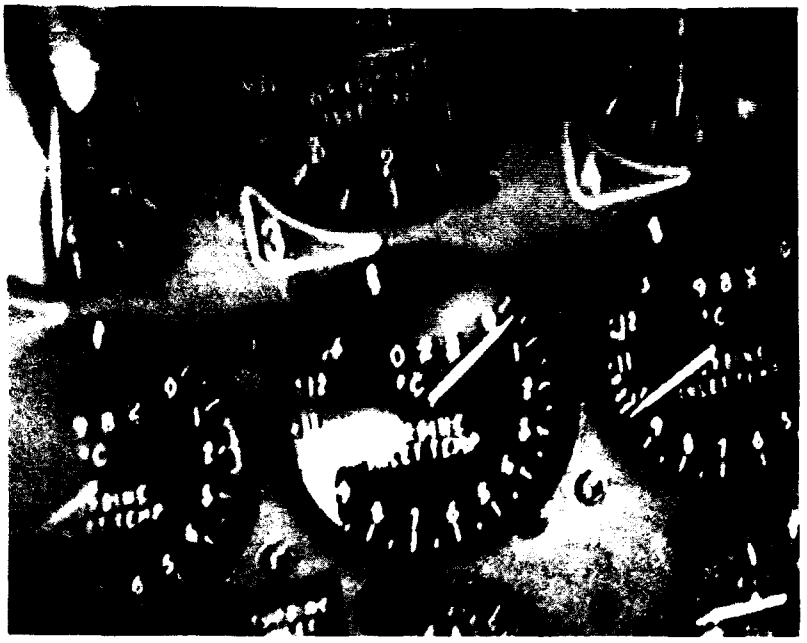

FIGURE 3. FIRST TEST FLIGHT COLD SOAK No 3 ENGINE AT 25,000 Ft.

FIGURE 4. SECOND TEST FLIGHT COLD SOAK No 4 ENGINE AT 25,000 Ft.

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